Comparative study on population age structures between *Adenophora lobophylla* and *A. potaninii* [1)]

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Abstract Comparing with an affinity and widespread species *Adenophora potaninii,* the age structures of *A. lobophylla* population, an endangered plant species were studied. 29 sample plots were investigated in the centered distribution area, Jinchuan county from altitude 2 300 m to 3 400 m. The main factors which influence the population age structures of *A. lobophylla* were analyzed. The principal characteristics of *A. lobophylla* populations are that the number of seedling and the density of population are much less than these of *A. potaninii* population. Below altitude of 2 700 m, the age structures of most *A. lobophylla* populations show the declining status, only above altitude of 2 700 m they are stable, while age structures of all populations of *A. potaninii* populations at corresponding altitude perform stable and developing features. The age structure patterns, relations between age (x) and number of individual (y) of stable populations of *A. lobophylla* can be expressed by equation: $y = e^{(a-bx)}$, and the longest life span is 25a. Whereas *A. potaninii* populations can be expressed by the equation: $y = ax^{-b}$, and the longest life span of individual is 21a. The external factors, which constrain the extension of *A. lobophylla* population, are extreme environmental conditions such as serious drought, external disturbance and low temperature.
Key words: *Adenophora lobophylla* population, *A. potaninii*, Age structure, Endangered plant.

Introduction

Plant number dynamic depends on the number of birth, death, emigrant and immigrant (Pielou 1977; Silvertown 1982). The plant age structure is the result of interaction between the plant viability and the environmental factors (Grawley 1991). Study on the endangered plant population age structure is very significant for appraising the population dynamic and population developing tendency. It not only explains the population status but also provides the scientific reference for conservation.

The works on the endangered plant population dynamic have been carried out for many years, and the age structure patterns of some endangered species have been reported (Fiedler 1977; Mehrhoff 1989). However, compared with an affinity and widespread species, study on the age structure patterns of a typical endangered plant population is rare.

Adenophora lobophylla is a typical endangered plant species in China (Zhang *et al* 1998). Owing to its importance in ecology, *A. lobophylla* has been selected as a type to study recently. The works on genetic diversity and morphology variation have been reported (Ge Song, Hong Deyuan 1994; 1995 a, b). However, the knowledge on the age structure patterns of this species has been known little. Undoubtedly, the study on the age structures of *A. lobophylla* is very important basic work for explaining the endangered status and forecasting the tendency of population. The objectives of this research are to explain the population age structure features by comparing with the affinity widespread species (*A. potaninii*), and analyze the principal factors, which lead the populations to be endangered status in order to provide the reference for the analysis on dynamic of populations and conservation measures.

Materials and methods

A. lobophylla is a perennial herb. It distributes only in the drought valley, on the east boundary on Tibet plateau, Jinchuan county (31°08′~31°58′ N, and 101°13′~102°19′ E) in Sichuan province (Hong 1983). The whole distributive area is not more than 5 000 km² (Zu *et al* 1997; Zhang *et al* 1998).

A. potaninii, an affinity to *A. lobophylla,* is generally recognized as a stable and widespread species. It ranges from the northeast, the northwest to the southwest of China (42°~26° N, and 95°~125° E) (Hong 1983). In order to make the comparison clear, we just selected Markang county as its investigating place where it is adjacent to Jinchuan county, and in 1950s, *A. lobophylla* also distributed there. So, the so-called populations of *A. potaninii* actually are the

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populations which just distribute in Markang county (31° 35′~32° 24′ N, 101° 17′~102° 41′ E) in this research.

In this area, it is warm temperate monsoon climate with clear dry season (November~April) and rainy season (May~October). The mean annual rainfall is 616.2 mm. The mean annual temperature is 12.8℃. (Zhang 1992). There are a few kinds of soil in this area (Hu 1990), which are mainly hilly drab soil, hilly brown soil and dark brown soil, in which pH is 6.3~7.7. The organic material content is 2.8%~8.2%; the soil moisture is 6.5%~23%. At altitude 2 000~2 600 m, the vegetation is mainly composed of xerox-spur-bush and xerox-herb communities. At altitude 2 500~3 400 m, it is sub-high mountain conifer-broad mixed forest. At altitude 3 400~4 000 m, sub-high mountain conifer forest (Zhang 1992). *A. lobophylla* lives in those different communities from altitude 2 300 m to 3 400 m, and *A. potaninii* ranges from 2 600 m to 3 500 m.

During studying process, the same methods to deal with the data from the indoor or field investigation for two species were adopted. 29 sample plots of *A. lobophylla* were disposed on different altitudes from 2 300 m (the low limit) to 3 400 m (the high limit). And 21 sample plots of *A. potaninii* were investigated from 2 600 m (the low limit) to 3 500 m (the high limit). In every interval of altitude 100m there are about 2 plots. The areas where there are likely rational age structure and higher population density were selected as sample plots for two species. The plots usually were 8~70 m^2, and in this paper, the individual number per 100 m^2 has been calculated in order to compare different populations. After investigating environmental factors, all individuals in the plots were dug up from root as carefully as possible in order to measure further in the laboratory. The age of every individual was identified by its bud scars on the perennial corona (Zu *et al* 1997). According to altitude and environmental condition, names of 5 populations have been given by altitude scope. They are the different populations: altitude 2 300~2 500 m; 2 500~2 700 m; 2 700~2 900 m; 2 900~3 100 m; 3 100~3 400 m. The populations of *A. potaninii* have been dealt with in the same way.

Results and discussion

The analysis on characteristics of age structures of *A. lobophylla* populations

The all age structures of *A. lobophylla* populations we have investigated can be classified to be 2 kinds easily: the declining and stable types. In this work, there are 2 populations at altitude 2 300~2 500 m and 2 500~2 700 m which show the declining characteristics (Fig. 1. a, b). The 3 populations, at altitude 2 700~2 900 m, 2 900~3 100 m and 3 100~3 400 m, show the stable characteristics (Fig. 1. c, d, e). In addition, some *A. lobophylla* populations in the special habitats below altitude 2 700 m perform stable characteristics. In this research, only 1 population at altitude 2 300~2 400 m was found, its features is similar to that of populations above altitude 2 700 m (Fig. 1. f). When all (29) sample plots were merged, we can get the average age structure of whole population (Fig. 2), whose main characteristics (density of population, young seedling number) represent middle value between the stable and declining populations. It includes the all information from the comprehensive interaction between the viability of *A. lobophylla* populations and the environmental factors.

Generally, a stable plant population always shows regularity on its rate of birth, death, emigrant and immigrant (Grawley 1991; Zhu 1993). Although the every stable population of *A. lobophylla* performs its special features, the common regularity is clear. The relation between age (*a*) and the individual number of population can be expressed by: $y = e^{(a-bx)}$ successfully after *F*-test. (*y*: the number of individuals at given age; *x*: the age; *a*, *b*: parameters in Table 1). Unfortunately, the declining populations at altitude 2 300~2 500 m and 2 500~2 700 m could not be expressed by this kind equation.

Analyzing the different populations of *A. lobophylla,* we can find that below altitude 2 700 m, most populations perform the declining characteristics; and there is the tendency that *A. lobophylla* population withdraws from lower to higher altitude. Generally, in these populations, the number of young individual is small.

Therefore, there is no sufficient resource for recruitment and reproduction. In addition, the mean density of population (1.8/100 m^2) at every age stage is lower, much less than that (4.3/100 m^2) of stable populations at altitude 2900~3100 m. This situation shows that most populations in this area can not normally regenerate. And it inevitably leads the distribution area to become smaller and smaller. Finally all populations of *A. lobophylla* go to extinction. From this phenomenon, the endangered process in the time and space of *A. lobophylla* population could be viewed.

The populations of *A. lobophylla* as an endangered species do not always perform declining characteristics. Above altitude 2 700 m almost all populations we investigated performed stable characteristics. Their density of population is higher, the number of seedlings is larger, and the fluctuation of individual number at different ages is smooth. Therefore, there are sufficient resources of recruitment and reproduction for maintaining the scope of population or extending their number and space. Even below altitude 2 700 m, it is possible for some small populations to survive, which perform the stable characteristics.

Table 1. The equations on the relation between the age and the individual number of the stable populations of *A. lobophylla* at different altitudes (alt.)

Alt. /m	Number of plots	Equations	r	DF	F. $Rat.$	$F_{0.01}$
2 300~3 400	29	$y = e^{(3.251-0.150x)}$	- 0.944	1, 13	106.40	9.1
2 300~2 400	3	$y = e^{(4.521-0.153x)}$	- 0.979	1, 9	210.10	10.6
2 700~2 900	7	$y = e^{(4.211-0.192x)}$	- 0.982	1, 10	268.17	10.0
2 900~3 100	3	$y = e^{(4.114-0.123x)}$	- 0.915	1, 10	51.50	10.0
3 100~3 400	3	$y = e^{(3.608-0.174x)}$	- 0.937	1, 9	65.10	10.6

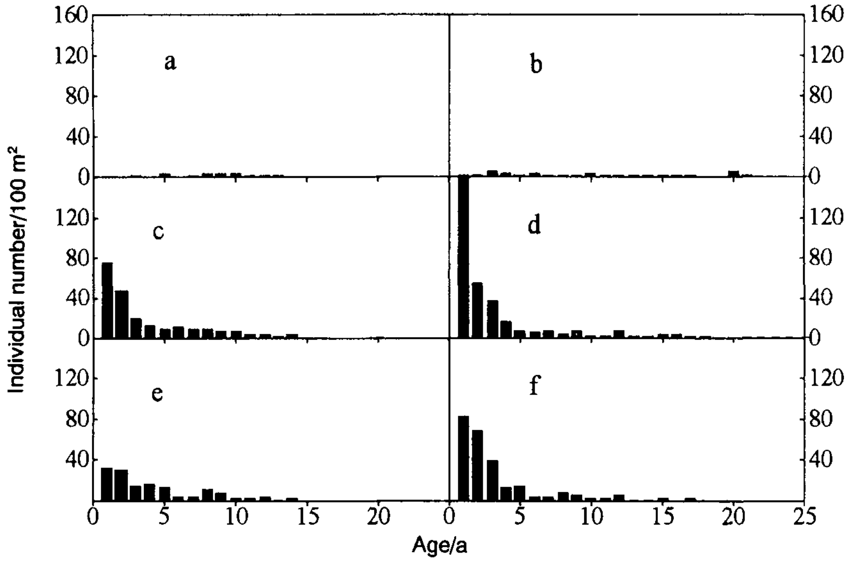

Fig. 1. Age structures of 6 populations of *A. lobophylla* from 2 300~3 400 m

a. alt. 2 300~2 500 m; b. alt. 2 500~2 700 m; c. alt.2 700~2 900 m; d. alt.2 900~3 100 m; e. alt. 3 100~ 3 400 m; f. 2 300 ~2 400 m in special habitat

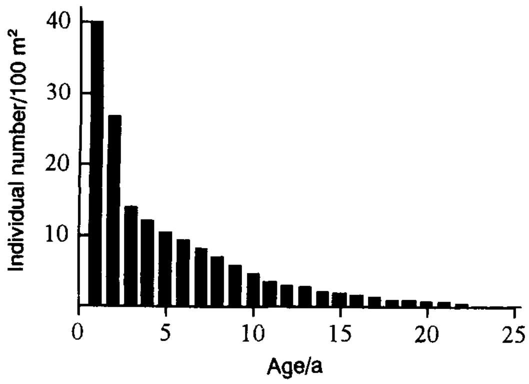

Fig. 2. Age structure of whole populations of *A. lobophylla*

However, these populations were restrained frequently in the special favorable habitat, the low part of slope or the thorny shrub communities. This phenomenon seems to imply that *A. lobophylla* population in the favorable environmental conditions could maintain their scope and number. All populations of an endangered species are composed of the stable, developing, and declining populations.

Analysis on the relation between the environmental factors and age structures of different populations shows that the extreme drought, disturbance and lower temperature are most important external factors, which influence the age structure. The area below altitude 2 700 m is a typical drought valley with clear dry season and wet season. Usually the natural vegetation has been destroyed completely. The barren land on the mountain slope and serious soil erosion can be found everywhere. The disaster drought occurs frequently. In addition, owing to near to the residential area, on the one hand, the local farmers collect it as a kind of Chinese medicine, on the other hand, the farmer use the slope for grazing sheep and cattle. It is difficult to find the place where there are suitable environmental conditions for *A. lobophylla* population to survive. However, as the altitude increases, the rainfall increase and the evaporation and temperature goes down. Above altitude 2 700 m, the drought condition becomes alleviated during dry season. The change of climate is corresponding to the age structure of *A. lobophylla* populations chang-

ing from the decline to the stable type. At the same time, as altitude increase, the external disturbance has been reduced because it is far from the residential area. It is easy to understand that most populations above altitude 2 700 m perform the stable characteristics.

Compared the 3 populations, above altitude 2 700 m, population density at altitude 2 900~3100 m is the highest, and the population at 2 700~2 900 m merely takes the second place (Fig.1. c, d). This situation shows that at altitude 2 700~3 100 m, the composition of environmental factors achieved optimum level for *A. lobophylla* populations to survive. This result tallies with the conclusion that we got from the analysis on individual growth regularity of different populations of *A. lobophylla* (Zhang *et al* 1998). Although the population at altitude 3 100~3 400 m (Fig.1. e) shows the stable features, the density of population is not high whereas the number fluctuation of population is larger than that at altitude 2 700~3 100 m. This situation shows its some declining signs. The reason is attributed to the lower temperature. Because the altitude 3 400 m is the highest limited boundary for *A. lobophylla* population to survive, and the water condition, external disturbances have been relaxed. On the other hand, the longest span of this population is only 15 a, which implies that the *A. lobophylla* population has changed its survival strategy under low temperature.

The analysis on general characteristics of the age structure of *A. potaninii* populations

In this area, the *A. potaninii* population distributes at alt. 2.600~3 500 m. Main characteristics of *A. potaninii* populations are: 1). Each *A. potaninii* population performs the stable appearance from altitude 2 600 to 3 500 m; 2). The individual number of each population decreases as the age increases, especially decreases rapidly at 1-3 years old; 3). Density of every population is higher, and age structure is reasonable, which shows that the populations have stronger adaptation and resistance to unfavorable environment. And each population has sufficient resource of recruitment and reproduction. Therefore, it is reasonable for us to believe that the *A. potaninii* population is stable or developing (Fig. 3; Fig. 4).

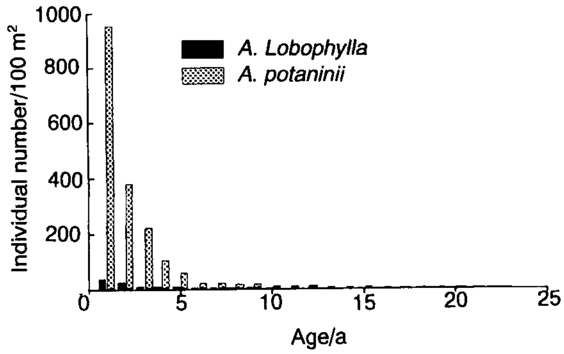

Fig. 3. Comparison on the whole population age structures between *A. lobophylla* and *A. potaninii*

The relations between age (year) and individual number of *A. potaninii* populations could be expressed by the equation: $y = a\,x^{-b}$ (y: the number of individuals at given age; x: the age; a, b: parameters) after F-test (Table 2.). These equations also show that the populations of *A. potaninii* have sufficient young seedling bank, and have not involved the endangered problem.

Table 2. The equations on relations between age and the individual number of *A. potaninii* populations at different altitudes (alt.)

Alt./m	Number of plots	Equations	r	DF	F. Rat	$F_{0.01}$
2 600~3 500	21	$y = 39\,761\,247.3\,x^{-2.103}$	0.937	1, 12	86.2	9.3
2 600~2 800	6	$y = 17\,909\,769.6\,x^{-1.998}$	0.948	1, 11	97.8	9.6
2 800~2 900	5	$y = 7\,402\,569.9\,x^{-2.124}$	0.991	1, 9	509.1	10.6
2 900~3 100	4	$y = 7\,025\,050.9\,x^{-1.059}$	0.945	1, 10	84.1	10.0
3 100~3 300	4	$y = 16\,932\,457.7\,x^{-1.928}$	0.947	1, 11	97.1	9.6
3 300~3 500	2	$y = 3\,007\,876.5\,x^{-1.679}$	0.980	1, 8	196.4	11.3

The comparison on population age structures between *A. lobophylla* and *A. potaninii*

The whole population of *A. potaninii* and population of whole *A. lobophylla* perform their population common characteristics respectively. The main differences between two species are:1). Difference of density is much larger. The number of one-year-old seedlings of *A. potaninii* population is 964 per 100 m², 24.7 times more than that of *A. lobophylla* population. Even if the age increases the difference decreases. At least, the density of *A. potaninii* population is 1.7 times more than that of *A. lobophylla* population (Fig. 3); 2). The regression equation of whole population of *A. lobophylla* is $y = e^{(3.251-0.150x)}$, whereas that of *A. potaninii* is $y = 39\,761\,247.3x^{-2.103}$. 3). The longest life span of *A. lobophylla* population is 25 years old. Whereas *A. potaninii* population is 21 years old, which performs the different survival strategies of two species. It is obvious, if the *A. potaninii* population is recognized as

a stable population, the *A. lobophylla* population should be a declining population.

At different altitudes, the pairs of *A. lobophylla* population and *A. potaninii* population show differences respectively. 1). The densities of 4 populations of *A. potaninii* all are much bigger than that of *A. lobophylla* populations respectively at corresponding altitude scopes. The biggest difference is at altitude 2 500~2 700 m, the number of seedling at one year old of *A. potaninii* population is 23 times more than that of the *A. lobophylla* population. The smallest difference is at altitude 2 900~3 100 m, the number of the *A. potaninii* population at one year old is 2.3 more times than that of *A. lobophylla* (Fig.4); 2). All of 5 populations of *A. potaninii* from 2 600 to 3 500 m perform the stable characteristics (Table 2). Only 3 populations of *A. lobophylla* above altitude 2 700m and 1 population in the special habitat at altitude 2 300~2 400 m perform the stable characteristics, the others below altitude 2 700 m perform declining characteristics (Fig.1; Fig. 4).

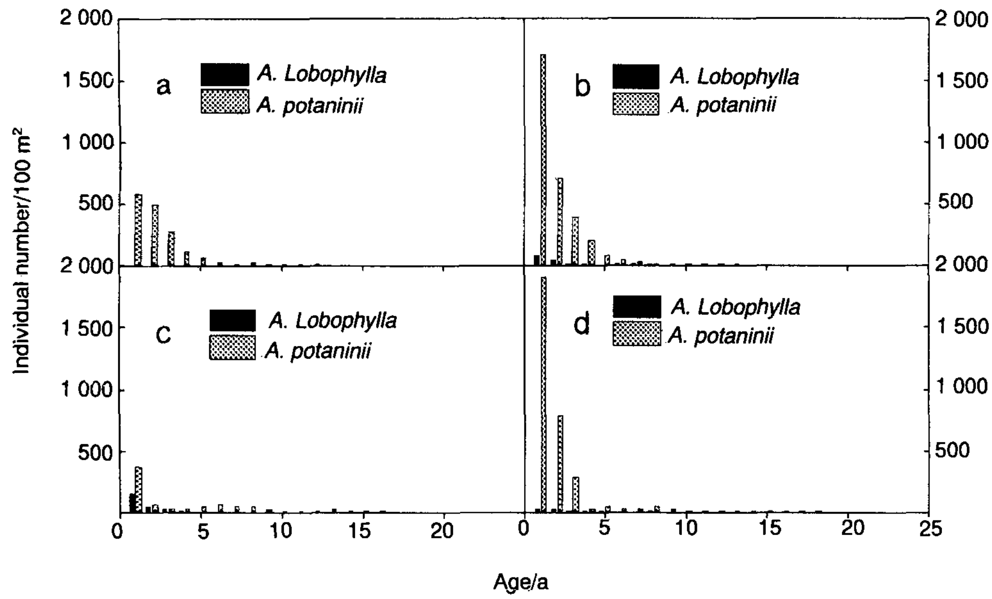

Fig. 4. Comparison on age structures of 4 population pairs at corresponding altitudes between *A. lobophylla* and *A. potaninii*

a. *A. lobophylla* alt. 2 600~2 800 m, *A.potaninii* alt.2 500~2 700 m; b. *A. lobophylla* alt.2 700~2 900 m, *A. potanini;* alt.2 800~2 900 m; c. *A. lobophylla* alt.2 900~3 100 m, *A.potanini* alt.2 900~3 100 m; d. *A. lobophylla* alt. 3 100 ~3 400 m, *A. potanini* alt.3 100~3 400 m.

The differences between two species populations have shown that the defects of *A. lobophylla* population in the viability. At the altitude 2 900~3 100 m, *A. lobophylla* population has better environment to live, and the difference of two species is minimum. This situation shows that the suitable habitat of *A. lobophylla* population is limited. The number of seedlings of *A. lobophylla* population is the key endangered evidence. Without sufficient seedling for recruitment, it is inevitable for *A. lobophylla* population to go decaying.

Undoubtedly, The external factors play an important role in the process for *A. lobophylla* population to be endangered. However, under the similar environment, one species involved in the endangered status, the other grows normally. We could assume the reason for endangerment to be the inherent defect. Both of *A. lobophylla* and *A. potaninii* are the accompanying species in the communities in which they live. Their viability depends on their own competition, adaptation, and resistance to unfavorable conditions. The higher density, larger individual number of every age stage of *A. potaninii* population shows stronger viability, while *A. lobophylla* population exposes some defects on these aspects.

Conclusions

The characteristics of age structures show that *A. lobophylla* population is a declining population as a whole. However, above altitude 2 700 m in this area, most populations perform the stable characteristics. The suitable environmental condition for *A. lobophylla* to survive is very limited, only at altitude 2 700~3 100 m in this area.

The factors that lead *A. lobophylla* populations to be endangered status are not only the external conditions but also itself inherent defect. The external unfavorable factors are assumed to be the extreme drought, disturbance from human being and low

temperature. Whereas inherent factors are population own competition, adaptation, and resistance to unfavorable condition.

Below altitude 2 700 m, the extreme drought environmental condition is due to the destruction of vegetation and environmental to a great extent. Therefore, the stopping destroying from mankind immediately, protecting natural vegetation, planting trees and grass and trying to restore ecological equilibrium are the imperative measures for conservation of *A. lobophylla* population.

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